New Media for 1-pass Printing Applications

Charlie Zhou, Haowen Yu, Xulong Fu, Pere Canti, Ana de la Rosa, and Lisa Underwood, Hewlett-Packard Co.; San Diego, California (USA)

Abstract

PageWide technology is an inkjet breakthrough that dramatically increases printing speed. The speed increases comes with some integration challenges. All of the ink is laid down in a single pass, so there is heightened sensitivity to missing nozzles, aerodynamics, and ink flux. Media is a key enabler for delivering customer requirements. In the CAD and GIS market, productivity is critical. With speeds up to 10x traditional inkjet, drytime and handleability are risk areas. HP's ColorPro technology enables excellent print quality with high Kod and saturated color, but with less ink. This helps both dry time and cost per copy. In the retail graphics and posters market, large uniform area fills are required, which is a challenge for 1-pass page-wide technology. HP's Production Poster technology has specially developed coating that tunes the dot size to deliver vibrant colors, while helping to hide missing nozzles, eliminating printing defects, and improving handleability. The result is a complete system where the ink, printer and media work together to deliver print quality at speeds not achievable with scanning inkjet technology.

PageWide Technology and Challenges on Media

HP PageWide technology uses more than hundreds of thousand tiny nozzles on a stationary printhead that spans the width of a page, delivering multi-colors ink onto a moving sheet of paper under a single pass to achieve the super-fast printing speed. Figure 1 shows HP PageWide XL 8000 Printer which could print up to 30 D/A1 pages per minute. Under such a printing condition, the challenge to the printing media is enormous.

Figure 1. HP PageWide XL 8000 Printer

While the printing speed is increased dramatically with 1-pass technology, the 1-pass printing puts 100% of the ink from each nozzle / printhead down all at once and is therefore more demanding on the ability of the paper to handle all of the ink in a very short amount of time. Different from the scanning type printhead, which moves over the same area of paper multiple times, the printhead used in HP PageWide technology is fixed and spans the whole print zone. All the images are generated by a single pass under the printhead, the random missing nozzle is inevitable, which will make some printing defect on the final print-out. Figure 2 below shows one example of missing nozzle on the black color under the microscope. The white line on the left is caused by two missing nozzles and the one on the right is caused by one missing nozzle.

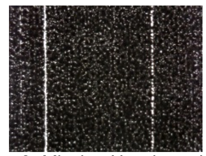

Figure 2. Missing Nozzle under the Microscope

On the other hand, while the media is able to absorb big amount of the ink in very short period of time, media will tend to expand immediately after printing and will cause the post-printing curl, which will increase the difficulty for stacking at stacker. How to use media coating technology to develop a media which could absorb ink faster and doesn't cause much post-printing curl will be another challenge.

Moreover, with PageWide technology, the media is continuously moving through the printhead with high print speed, which may cause some aerodynamic print defect. Figure 3 below shows one example of aerodynamic print defect on orange color. Aerodynamic print defect is more visible on certain color than the others. It is also more visible on some media than the others. When aerodynamic defects occur, the uniformity of color and good image quality could not be achieved. We need media coating technology to help hide the defect and, at the same time, without sacrificing other key performances, such as bleed, coalescence, mottle, etc.

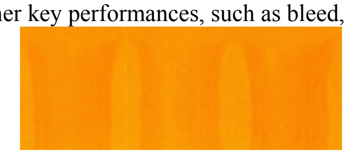

Figure 3. Aerodynamic Print Defect

For poster application, it demands high quality printed pages. High image quality, color saturation, text sharpness are required. How to let the ink dry faster and still keep the high ink density, color Gamut, good bleeding and coalescence performance will be another challenge. Poster applications associated with high ink coverage, large ink area fill, wide range of color ink usage will make the situation even more complicated.

New Media Performance in These Challenging Areas

Ink, printer and media is a complete system, in which they always work together to achieve high print quality at high print speed. In current paper, we only focus on new media development under 1-pass printing. A new media is developed for 1-pass poster printing applications focusing on these challenging areas.

New media drytime is much improved and meets fast drying requirement under 1-pass printing with or without printer drying system. The new media is designed to have an optimized absorption rate. On one hand, ink can be absorbed by the media at a fast rate so that the ink does not have a chance to interact and cause bleed and / or coalescence issues and also not cause any ink transfer to any rollers inside the paper path of the printer. On the other hand the new media is also constructed in order to avoid any excessive absorption of the ink so that ink optical density and color gamut are decreased. The faster the printing speed and the higher the amount of ink used, the higher is the demand on faster absorption from the media. A good diagnostic plot with maximum ink density, such as secondary colors, would be prone to coalescence and a pattern of lines of the primary and secondary colors passing through area fills of primary and secondary colors would be prone to bleed. If no bleed or coalescence is present at the desired printing speed, the absorption rate would be sufficient. Bristow wheel measurements can be used for a quantitative measure of absorption on media wherein a fixed amount of a fluid is applied through a slit to a strip of media that moves at varying speeds. (The Bristow wheel is an apparatus also called the Paprican Dynamic Sorption Tester, model LBA92, manufactured by Op Test Equipment Inc.) Optimized absorption rate is determined and verified during the media development.

Gamut and L*min are two important performances for print quality. New media Color Gamut and L*min meet the requirement for poster application. The results are similar to what we normally achieve for poster application with scanning inkjet technology. Gamut measurement (Gamut) represents the amount of color space covered by the ink on the media. Gamut volume is calculated using L*a*b* values of 8 colors (cyan, magenta, yellow, black, red, green, blue, white) measured with an X-RITE®939 Spectro-densitometer (X-Rite Corporation), using D65 illuminant and 2° observer angle. L*min value testing is carried out on a black printed area and is measured with an X-RITE®939 Spectro-densitometer, using D65 illuminant and 2° observer angle. This measure determines how "black" the black color is. A lower score indicates a better performance.

New media has no visual color-to-color bleed at designed print speed. Bleed testing is carried out with a bleed stinger pattern. 1016 micron lines (or 40 mil, where 1 mil = 1/1000th of an inch) of cyan, magenta, yellow, black, red, green, blue inks, passing through solid area fills of each color, are printed and scanned. The bleed is evaluated visually for acceptability. The samples are given a rating score according to a 1 to 5 scale (wherein 1 means the worst performance and 5 represents the best performance).

New media shows good coalescence performance at designed print speed. The coalescence is also evaluated visually for acceptability. The samples are given a rating score according to a 1 to 5 scale (wherein 1 means the worst performance and 5 represents the best performance).

New media provides printed images that do not show visible print mottle. Print mottle or mottling is a defect that often presents as uneven random color patterns in a large area of an image. It is believed that uneven absorption of ink in the coating layer causes this defect, a result of uneven coat weight / thickness on base paper, and / or variation of the coating layer. For coated paper, the underneath base paper is usually rougher than the final sheets. During coating process, the thickness of the coating layer may vary with any bumps and valleys on the base paper surface. Even with precise coating methods, there is often uneven coating thickness across the web. Since the absorption of liquid in coating layer is different than absorption in the base paper, variation of the coat weight is a major cause of print mottle. New media is considered to have improved coat weight control and improved mottle performance.

New media is designed to help to hide "missing nozzle" defect. With the coating technology used in new media, the "dot gain" is optimized and well controlled. The "dot gain" is the difference between the dot size on the source file and the corresponding dot size on the printed result. It refers to diameter of halftone dots increases during printing process. The got gain makes material looking darker than intended and certain degree of dot gain is desirable in order to hide "missing nozzle" defect during 1-pass high speed inkjet printing. However, excessive dot gain need to be avoid since it will results ink bleed defects and damage edge quality of print-out. Murray-Davies equation, can computes the dot gain from density measurements according to the Equation 1 below.

$$Dot\ Gain = \frac{1-10^{(D_0-D_N)}}{1-10^{(D_0-D_{100})}} \times 100 - N \qquad (1)$$

In this equation, D_0 is the measured density of a 0 % dot (i.e. unprinted substrate), D_{100} is the density of a 100% dot, and D_N is the density of the sample N % dot (very often, N = 50). The "missing nozzle" defect measurement is a visual evaluation on how well the media could hide missing nozzles. Several diagnostic plot are printed in which missing nozzles are purposely create (nozzle that consistently fails to eject drops on the black, cyan and magenta color).

New media is designed to help hide aerodynamic defect. This area is also related to absorption rate and dot gain. With optimized absorption rate and dot gain, new media could better hide aerodynamic defect without losing other key performances. The aerodynamic defect measurement is a visual evaluation of the banding on certain color wherein the uniformity of the color is evaluated visually.

New media is designed to have improved curvature control. By "curvature", it is meant herein the upward or downward curve of edges of a planar sheet. If a media has too much positive curvature (i.e., toward the image printing side), which can cause inkjet printhead to scrape the paper and cause a print jam or print defect. If a media has too much negative curvature (i.e., toward the back side), which can cause sheet feeding problems in the paper handling tray. Not bonded to any theory, it is believed that the cause of curvature on media is due to unbalanced stress distribution on each side of the media. The environment, especially the moisture from media storage and application will make the stress even more unbalanced. With improved curvature control, new media does not present any "curvature issue" to ensure good printer running-ability under high speed printing. Especially, new media does not present any obvious post-printing "curvature issue" at stacker.

There are many mechanisms causing unbalanced stress and curvature. Many traditional curvature control methods focused on either preventing curvature during paper making process, such as dryer / drying process control, or removing the curvature using some decurling methods, such as steam or decurl bar. Traditional curvature control methods employed to improve the curvature performance of new media. Other than that, new media structure was designed to have two sided coating instead of single sided coating to remove the two-sidedness and make more flat media. Especially, after the printing, the image printing side absorbs big amount of ink in short period of time, which causes unbalanced stress and strain. The backside coating could help to counter balance that and prevent severe post-printing curvature. In addition, both coatings have water soluble binder, such as PVOH, which will respond to the environmental humidity changes. Backside coating is designed to respond in a way similar to the image printing side coating, which helps the media to remain flat or nearly flat at all environmental conditions. For example, when the media is conditioned in a hot, dry condition (such as 32°C/20% RH), the backside coating will shrink, and that shrinkage will counter balance the shrinkage stress from image printing side coating. In Figure 4, it shows media in a hot, dry condition.

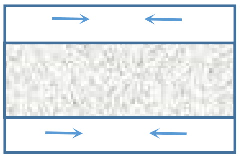

Figure 4. Media in a Hot, Dry Condition

The curvature performances is evaluated by measuring and then average the height of the four corners on 8.5''x 11" (216 mm x 279 mm) media sheets. Sample sheets are tested under 5 different temperature / humidity conditions. They are 23°C/50%RH, 15°C/20%RH, 15°C/80%RH, 30°C/80%RH and 32°C/20%RH. In Figure 5 below, it shows new media curvature performance at 4 hours and 24 hours under these 5 temperature / humidity conditions.

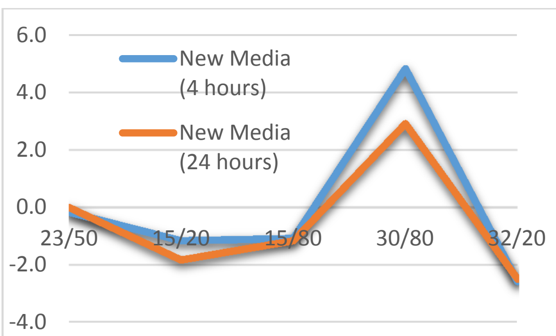

Figure 5. New Media Curvature Performance

Some media key performances are listed in the Table 1 and Table 2. For nozzle defects performance, we print designed diagnostic plot in which we purposely create one missing nozzle (one nozzle that consistently fails to eject drops) and 2 missing nozzles on the black, cyan and magenta color. Visually inspect printed samples to check how well the media could hide the missing nozzle. In the visual scale, 5 is the best, media could fully hide one missing nozzle. 1 is the worst, media could not hide any part of one missing nozzle and missing nozzle is obvious to see in all 3 colors. The other visual scores are defined for the situations in between the extremes.

Similarly, for aerodynamic defect performance, we print diagnostic plot with selected color designed for detecting aerodynamic print defect. Then we visually inspect the uniformity of the color. In the visual scale, 5 is the best, media is defect free and color is uniform without any banding. 1 is the worst, media has severe aerodynamic print defect and there is obvious color banding. The other visual scores are defined for the situations in between the extremes.

The other media key performances include Gamut, L*min, bleed, coalescence, drytime and mottle. Gamut and L* min are measured with X-RITE®939 Spectro-densitometer (X-Rite Corporation), using D65 illuminant and 2° observer angle. For coalescence and bleed performance, as we mentioned before, we print designed diagnostic plot with maximum ink density, such as secondary colors, which would be prone to coalescence and a pattern of lines of the primary and secondary colors passing through area fills of primary and secondary colors, which would be prone to bleed. For mottle performance, we print diagnostic plot with selected color designed for detecting mottle. Similarly, for drytime performance, we print diagnostic plot with both primary and secondary colors. In Figure 6, it shows one drytime diagnostic plot in black color. All these coalescence, bleed, mottle and drytime results are evaluated visually for acceptability. The samples are given a rating score according to a 1 to 5 scale (wherein 1 means the worst performance and 5 represents the best performance).

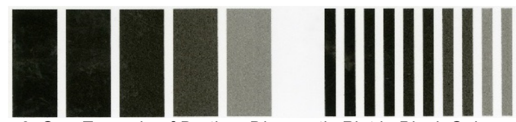

Figure 6. One Example of Drytime Diagnostic Plot in Black Color

Table 1: Media Key Performance 1

Sample ID	Overall Image Quality	Nozzle Defects	Gamut (K)	L* min	Bleed
New Media	Excellent	3	357K	12.8	4

Table 2: Media Key Performance 2

Sample ID	Aerodynamic Defect	Coalescence	Dry Time	Mottle
New Media	4.5	4	4	3

New Media Balanced Between Conflicting Attributes

Some media attributes are conflicting each other. Improving one attribute sometimes may lead to weakening another one. Bleed and "missing nozzle" hiding are one set of conflicting attributes. In order to hide "missing nozzle", we'd like to have larger dots. However, larger dots are usually related to worse bleed performance. New media balanced between bleed and "missing nozzle" hiding with optimized dot size.

Gamut and "missing nozzle" hiding are another set of conflicting attributes. We tested gamut and "missing nozzle" performance for different types of media. All printed samples are measured and evaluated visually. The test data are plotted in the Figure 7 below. It shows that, overall, the media with higher gamut tends to have lower "missing nozzle" score and the media with lower gamut tends to have higher "missing nozzle" score. New media balanced between gamut and "missing nozzle" hiding with good overall image quality.

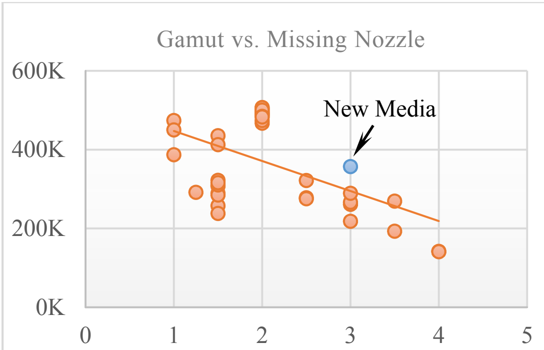

Figure 7. Gamut vs. Missing Nozzle

New media provides printed images that can be present in various surface finishing such as matte, satin and gloss. In order to achieve high surface gloss, media needs to go through a calender or super calender step after the coating process. Under pressure and / or high temperature, the pores in the coating layer will deform, which might, in many cases, impact on ink penetration rate in the coating layer, and eventually impact on the drytime. New media balanced between gloss level and drytime to achieve required gloss level and, at the same time, still have acceptable drytime performance.

The Advantages of New Media over Competitive Media

We tested a lot of competitive media focusing on these key performance areas. The media performance is various. Some media is good at certain areas but not on the other areas. For example, media A has very good "missing nozzle" hiding performance but poor gamut. Media B has good gamut but poor "missing nozzle" hiding performance. The results for media A and media B are shown below.

Overall image quality is evaluated based on performance on all these key performance areas not only on certain areas. In Table 3 and Table 4, it shows the key performance for two of our competitive media.

Table 3: Competitive Media Key Performance 1

Sample ID	Overall Image Quality	Nozzle Defects	Gamut (K)	L* min	Bleed
Media A	Poor	4	142K	31.1	4.5+
Media B	Poor	1	474K	3.9	3.5+

Table 4: Competitive Media Key Performance 2

Sample ID	Aerodynamic Defect	Coalescence	Dry Time	Mottle
Media A	4.5+	3	5	2
Media B	4	3	3	5

Other Advantages of New Media

Other than good overall image quality mentioned above, new media also has some other advantages. New media can be imaged by various printing methods such as such as dye ink printing, pigment ink printing, latex ink printing, and dry toner (electrophotographic) printing with high image quality and durability. While it can be used in the high speed, large format printing such as Laserjet, Web Press and PageWide Array printing, it can be also used in desk-top small format and low speed printing.

Common paper coating manufacturing process is used to produce new media and it is made by high speed industry coater, which helps to keep cost competitive.

References

[1] E. Echt, "Polyvinyl Alcohol for Paper Coatings," Coating Materials Short Course, 2003.

[2] K.G. Hagen and J.R. Bowden, "Options for Controlling Convective Coating Dryers," TAPPI Journal, 1991.

[3] D.A. Leeman, "A New Approach to Moisture and Curl Control on Silicone Release Liners," TAPPI Journal, vol.77, no.5, 1994.

[4] T. Uesaka, C. Moss and Y. Nanri, "The Characterization of Hygroexpansivity," International Paper Physics Conference, 1991.

[5] W. Lu and L.A. Carlsson, "Influence of Initial Deflections on Curl of Paper," Journal of Pulp and Paper Science, vol. 27, 2001.

[6] W. Lu and L.A. Carlsson, "Influence of Viscoelastic Behavior on Curl of Paper," Mechanics of Time-Dependent Materials, 2001.

[7] V. A.P. Morris and W. W. Sampson, "An Investigation of Heat Curl in Newsprint," TAPPI Journal, vol. 81, no. 8, 1998.

[8] C. L.E. Eriksson, S. Cavlin, C. Fellers and L.A. Carlsson, "Curl and Twist of Paperboard – Theory and Measurement," Nordic Pulp Paper Research Journal, 1987.

[9] A. Nordstrom, L.A. Carlsson and J-E. Hagglund, "Measuring of Curl of Thin Paper," TAPPI Journal, vol. 80, 1997.

[10] P. Sunderland, A. Sollander, J.A. Manson and L.A. Carlsson, "Measurement of Process – Induced Residual Stresses in Linerboard," Journal of Pulp and Paper Science, vol. 25, 1999.

[11] T. Uesaka, I. Kodaka, S. Okushima and R. Fukuchi, "History-Dependent Dimensional Stability of Paper," Rheologica Acta, 1989.

[12] C. Fellers, and L. Carlsson, in Handbook of Physical and Mechanical Testing of Paper and Paperboard (R. E. Mark, Ed.), vol. 1, Marcel Dekker, New York, 1983, Chap. 7.

[13] K. C. Mann and L. A. Huff, "Curl Control: A New and Unique Approach," Finishing & Converting Conference, 1991.

Author Biography

Charlie Zhou received his PhD in Polymer Materials from University of Birmingham in England (1992). He is now working in Media Supplies and Solutions Division at Hewlett-Packard Co.in San Diego, California. His work has focused on new media development on various HP printer platforms.

Haowen Yu received her PhD in Mechanical and Aerospace Engineering from Oklahoma State University (2007). Since then she has worked in Media Supplies and Solutions Division at Hewlett-Packard Co.in San Diego, California. Her work has focused on new media development on various HP printer platforms.

Xulong Fu received his MS in Paper Science from Georgia Institute of Technology (1994). He is now working in Media Supplies and Solutions Division at Hewlett-Packard Co.in San Diego, California. His work has focused on new media development on various HP printer platforms.